PORT AND OCEAN ENGINEERING UNDER ARCTIC CONDITIONS
TECHNICAL UNIVERSITY OF NORWAY

CANADIAN ARCTIC OPERATIONS EMPLOYING MANNED SUBMERSIBLES

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ABSTRACT

Up to the present only one firm in Canada has been engaged in the development and manufacture of the manned submersible, International Hydrodynamics Company Ltd. (Hyco). To date this firm has completed the manufacture of four submersibles.

The company had as its original objective the manufacture of a submersible as a salvage tool. Pisces I represents the realization of this objective and was completed in 1966. It was quickly appreciated that the manned submersible had a tremendous potential as the platform for undersea research, exploration, resource investigation, pollution monitoring, etc. Pisces II was manufactured under contract for Vickers Engineering Ltd., Barrow, England and represents design advances learned from the employment of Pisces I. Concurrent with the manufacture of Pisces II, the company built Pisces III to the same design for their own use. These craft were completed in 1969. The submersible diver lockout (SDL-1) was designed and manufactured during 1970 under contract to the Canadian Department of National Defence. Up to three of the crew of this submersible may be divers. The design will permit lockout operations at depths to 1000 feet. Delivery of SDL-1 was made in December 1970.

The Pisces submersibles have been employed on a wide range of work activities. These include operations in the Canadian Arctic Archipelago, Hudson Bay, and Lakes Huron and Erie. It is these operations which may be of interest to this conference and will be discussed in detail.

During a six week period in August and September of 1968, Pisces I made a series of 15 dives in the waters of the Canadian Arctic Archipelago to assess the feasibility of the manned submersible to undertake geological research, exploration and mapping of the sea floor. The support vessel during this operation was the Canadian Coast Guard Ship LABRADOR. The operation involved activities on behalf of the John Hopkins University, Maryland, U.S.A., the Defence Research Establishment Pacific, the Pacific Oceanographic Group of the Fisheries Research Board, and the Oceanographic Laboratory of the Bedford Institute.

During a seventeen day period during May 1970, Pisces III made a total of sixteen dives, eleven in Lake Huron and five in Lake Erie, in support of a research program involving two industrial companies, one Province of Ontario government agency, three Federal government agencies, three Canadian universities and one university situated in the U.S.A. The total program was co-ordinated by Dr. Peter G. Sly, Head, Limnogeology Section, Canada Centre for Inland Waters, Department of Mines, Energy and Resources.

During a four week period in August and September 1970, Pisces III undertook a series of exploration and working dives in Hudson Bay under contract to the oil exploration group Aquitaine Ltd. It is to be appreciated that a submersible is not capable of operating without the assistance of a support vessel embodying launch/recovery capability in addition to the normal logistics. The operation in Hudson Bay was as much characterized by the rapidity with which a new concept in support vessel (the Hudson Handler) was designed, built, and proven as by the demonstrated capability of the submersible to support oil exploration activities on the sea floor.

It is probable that the ways and means of employing manned submersibles in all aspects of Ocean Engineering activities present at least as much of a challenge to imagination as to engineering ingenuity, with Arctic conditions perhaps defining only the most difficult circumstances. It is therefore suggested that wide latitude on imagination may be allowed in looking ahead.

INTRODUCTION

Up to the present time only one firm in Canada has been engaged in the development and manufacture of manned submersibles, International Hydrodynamics Company Ltd. of North Vancouver, B.C. All of the Canadian Arctic operations employing manned submersibles to date have used submersibles built by this firm.

The company came into being in 1964 as a partnership of three working divers sharing the concept, one may almost say the dream, that a small, deep diving submersible vehicle could invoke a quantum jump in man's ability to perform useful tasks in the sea. They could see that such a vessel could go much deeper, and remain on task much longer, than a suited diver, that it could be used in research and exploration as well as in salvage and construction, and that it would permit a non-diving specialist of any discipline to visit sub-surface work sites under "shirt-sleeve" conditions while able to view the task with his own eyes.

They were not original in this concept. Such vessels have been performing as useful oceanographic work platforms since the early 1960's. One spur to their development has its origin in the program to rescue personnel from distressed military submarines by using specially designed miniature submarines as escape vehicles. But we can safely assume that the dream of unlocking the secrets of the ocean is as old as man's awareness, another challenge to man's quest for knowledge and the satisfaction of that insatiable curiosity which his unique physiological adaptions and miraculous intellect permit him to indulge in ever bolder measure.

Sometimes man's desire to satisfy his curiosity is greater than any other need, and it is far from clear to many people that the penetration of outer space has any greater purpose than curiosity satisfaction. In the case of aqua-space exploration, for which the manned submersible may be as a Soyuz or an Apollo, the need for food and natural resources may be the paramount incentive. To quote the late President John F. Kennedy, a man who certainly gave great impetus to the space program of the United States of America, "Knowledge of the oceans is more than a matter of curiosity. Man's very survival may hinge upon it."[1]

It is considered that the word submersible, which has already been frequently used above, should be defined with respect to its connotation in this paper. The term is applied to a range of sub-surface vehicles so diverse in configuration, capability and mission profile that it is difficult to be precise about the commonality implied. Perhaps the term has gained popularity primarily to distinguish this vehicle from the military vessel which the word submarine tends to bring to most people's mind.

In the context of this paper, a submersible is a vessel of very limited sea-keeping qualities capable of sub-surface activities but of such restricted mobility and self-restoration capability as to require a comprehensive logistics support facility adjacent to its work site. The submersible must be launched into the water at the commencement of a work cycle and recovered from the water at the termination of a work cycle, since all maintenance and restoration must be carried out with the submersible out of the water. The submersible must be tended by a surface vessel responsible for surface control and safety and acting as a communication link with the submersible.

Thus it is seen that the submersible is the diving element of an ocean engineering work system of appropriate form. As the submersible meets the full challenge of its future potential, it is apparent that the support facility must be an ocean going vessel, perhaps itself a specially configured submarine.

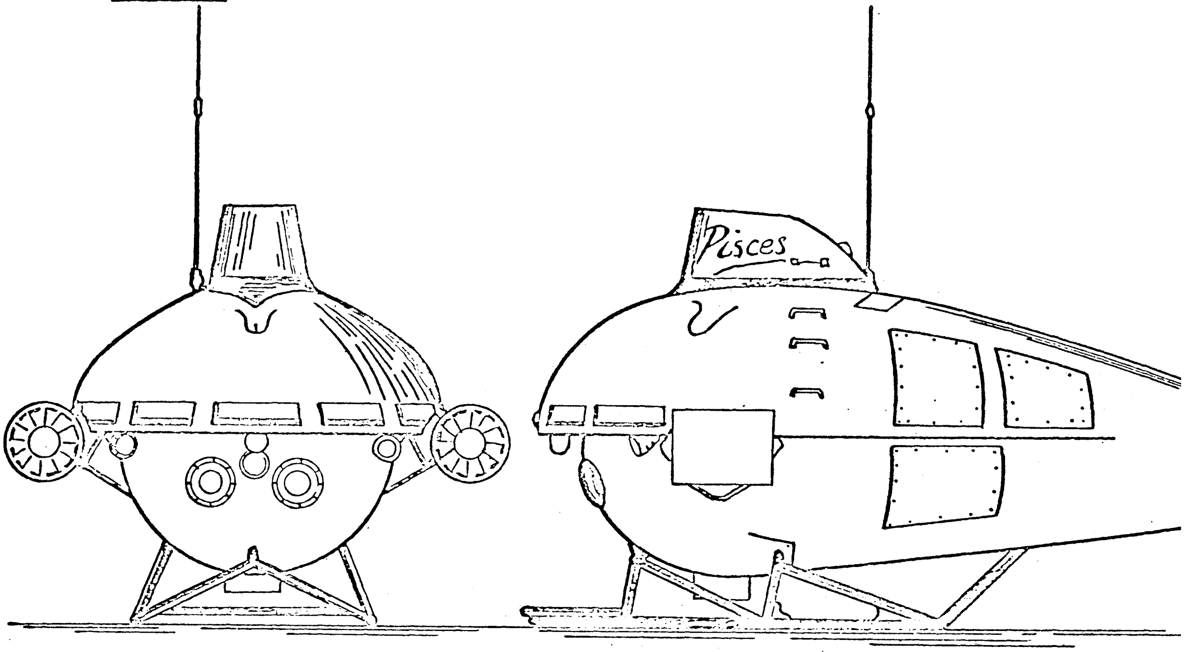
From its beginnings as a mobile, free swimming observation chamber, the manned submersible has evolved in capability and flexibility by the addition of manipulators, cameras, oceanographic instruments and sensors, dredging and coring devices, diver lockout chambers, etc. Much of this evolution has arisen following operations using jury-rigged equipments embarked to meet a particular task not foreseen in the submersible's original design, a not uncommon circumstance during the pioneering phase in the development of any new engineering work system.

Submersibles may be categorized by certain major characteristics. Thus there are unmanned, as well as manned, submersible vehicles. Also there are tethered as well as free swimming submersibles, and the tether may embody air supply lines and power input and communication cables, etc. And there is a growing number of submersibles having a diver lockout capability. Yet they remain small and not capable of protracted independent operation. Most are air and road transportable with obvious advantage. And since the full scope of the submersible's contribution in oceanology and ocean engineering is still not fully known, much design effort is expended in enhancing versatility in each new vessel that is manufactured, so that evolution may continue as rapidly as circumstances and safety dictate.

To date HYCO has completed the manufacture of four submersibles. Figures 1, 2 and 3 show major particulars of Pisces I, Pisces II and III, and SDL-1 respectively. Note that in all cases the

SUBMERSIBLES

PISCES I

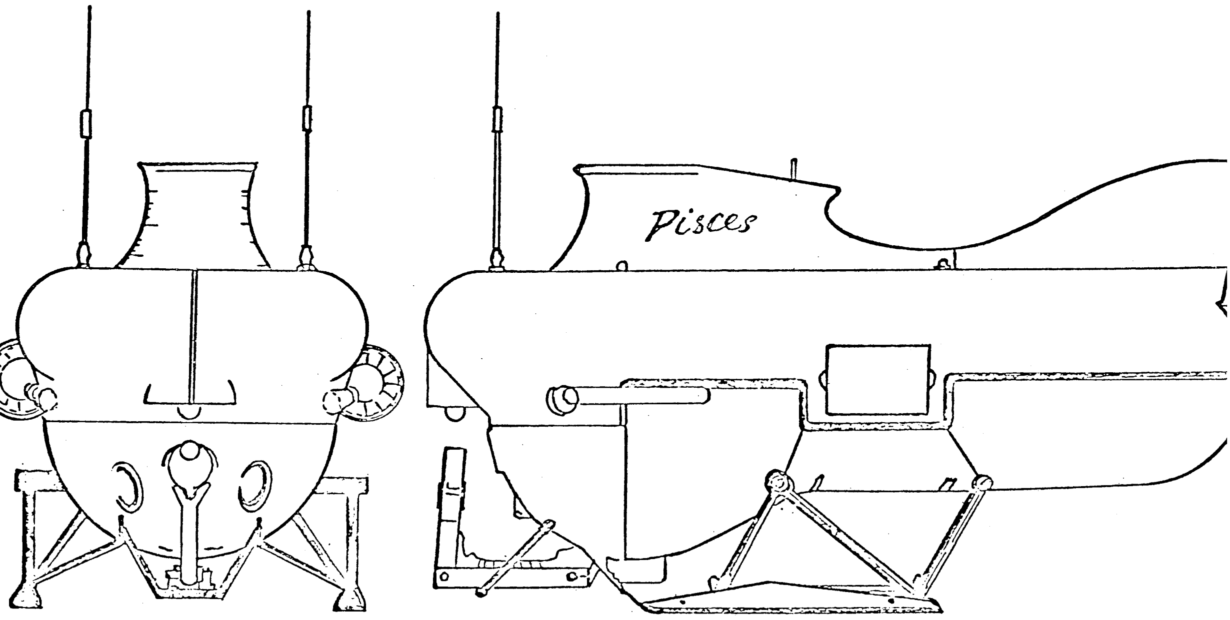


PISCES I

Length Overall	16.0 feet
Beam (extreme)	11.5 feet (reduces to 8 ft)
Height	10.5 feet (reduces to 8 ft)
Draft (surfaced)	7.5 feet
Weight	15,000 pounds
Operational Depth	1,500 feet
View ports; Material	Plexi glass
Inside Diameter	6 inches
Outside Diameter	12 inches
Thickness	6 inches
Quantity	3
Battery Capacity	550 ampere hours
Battery Type	Lead Acid
Payload	800 pounds including crew
Crew	1 to 3

Figure 1.

PISCES II and III

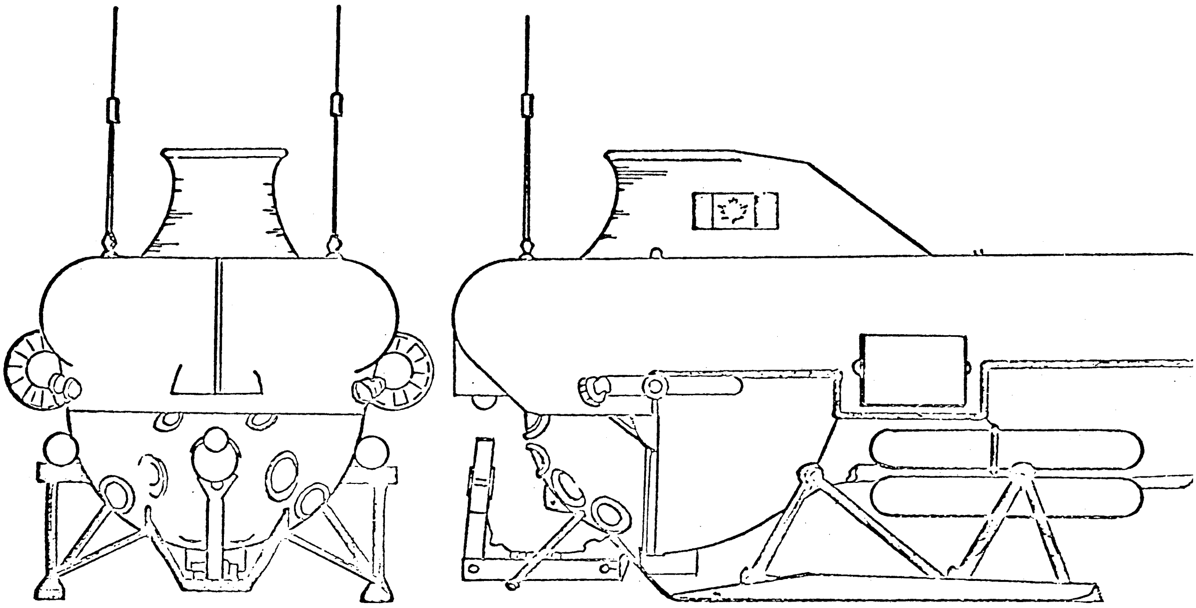


PISCES II and III

Length Overall	20.0 feet
Beam (extreme)	10.0 feet (reduces to 8 ft)
Height	12.0 feet (reduces to 9 ft)
Draft (surfaced)	8.8 feet
Weight	24,000 pounds
Certification Depth	3, 600 feet
Viewports: Material	Plexiglass
Inside Diameter	6 inches
Outside Diameter	14 inches
Thickness	3.5 inches
Quantity	3
Battery Capacity	400 ampere hours
Battery Type	Lead Acid
Payload	1500 pounds including crew
Crew	1 to 3

Figure 2.

SDL - 1



SDL-1

Length Overall	19.7 feet
Beam (extreme)	9.8 feet (reduces to 8.5 ft)
Height	10.8 feet (reduces to 8.3 ft)
Draft Surfaced	7.8 feet
Weight	28,630 pounds with 6 crew and 400 lbs in tanks
Certification Depth	2,000 ft
View Ports: Material	Acrylic
Quantity	10
Battery Capacity	495 ampere hours
Battery Type	Lead Acid
Payload	1300 lbs
Crew	1 to 6

Figure 3.

height and beam are reducible in order to permit air transport in a Hercules aircraft.

A fifth submersible, very similar to Pisces II and Pisces III, is in the course of manufacture for delivery to the Soviet Union Academy of Sciences in January 1972.

In addition, the firm has designed and sub-contracted the manufacture of an ocean going support vessel, the Hudson Handler. This vessel may be dismantled into sections and loaded onto eight flat cars for rail transport. Completed in 1970, the Hudson Handler is presently spending its second summer in Hudson Bay supporting Pisces III during oil exploration activities on behalf of the Aquitaine Company of Canada, Limited.

ARCTIC OPERATIONS

Canada's first Arctic Operation employing Manned Submersibles took place during August and September 1968, when Pisces I was invited to participate in Operation Icepack 8/68. This operation embraced a co-operative program to study the marine environment in the Canadian Arctic Archipelago and was carried out by personnel, based on the Canadian Coast Guard Icebreaker Labrador, from the Defence Research Establishment Pacific, the Bedford Institute of Oceanology, and the Pacific Oceanographic Group of the Fisheries Research Board of Canada. In addition to the Canadian scientists, representatives from John Hopkins University, Maryland, U.S.A. also participated.

The principal objectives of the program were:

(1) to retrieve five Recording Instrument Packages from the ocean floor after one year in situ,
(2) to make biological and physical oceanographic observations in selected areas,
(3) to assess the potential of the manned submersible as a means for carrying out studies in various scientific disciplines and under varying conditions of ice cover.

The only major modification made to the Labrador in preparation for its use as a submersible tender was the erection of a temporary heated shelter with removable roof and one side hinged at guard rail level. This shelter was considered necessary both to provide an adequate servicing hangar for Pisces I as well as to obviate the possibility of ice formation on the submersible if it were cooled below the freezing point and then launched into water in temperature equilibrium with melting ice. The shelter was adequate to both its functions. No trial was carried out to assess magnitude and effect of any icing which may have occurred if Pisces I had been launched cold.

However, in ice free seas, even slight rolling of Labrador seriously inhibited the handling of the submersible due to the pendulum action which occurred when Pisces I was hoisted by the ship's slow-acting crane and, in open water, diving operations had to be suspended when the wave or swell height exceeded one meter. In ice covered areas, diving depended upon the availability of stable polynyas within the ice field. As a safety measure, dives in such areas were made with a polypropylene rope loosely connecting the Pisces I to the ship.

Dived navigation was accomplished by dead reckoning against time and a directional gyro in Pisces I which was set to ship's head just prior to launch and checked just prior to submergence. The back-up navigation consisted of a sonar pinger suspended from the Labrador which permitted an acceptable back-up navigational performance using the Pisces I scanning sonar.

Pisces I completed 15 dives out of a total of 19 launches (Fig.4). Of the four aborted dives, two were caused by faulty scientific equipment, one by the electrical interference from the submersible's dc to ac inverter when attempting to use electronic equipment to record acoustic backscatter, and one as a consequence of salt water leakage into a main battery connector external to the pressure hull.

Much useful scientific work was accomplished in spite of the pioneering aspects of this program, and much useful experience was gained in the use of the submersible in this role and under these conditions. It was concluded that the combination of ship, helicopter and submersible gave an invaluable three dimensional visual and tactile capability to research in this forbidding region and it was recommended that serious consideration should be given to incorporating submersible housing, handling and maintenance facilities in all of Canada's Arctic Research ships.

The operation has been comprehensively reported upon. The relevant reports are listed as references 2, 3, 4 and 5 below for those seeking greater detail relative to particular areas of interest.

The second Operation to be considered took place during May 1970 in Lakes Huron and Erie, and involved the use of Pisces III. During this operation the submersible was under the operational control of the Canadian Department of National Defence, having been turned over to a naval crew then undergoing training in anticipation of

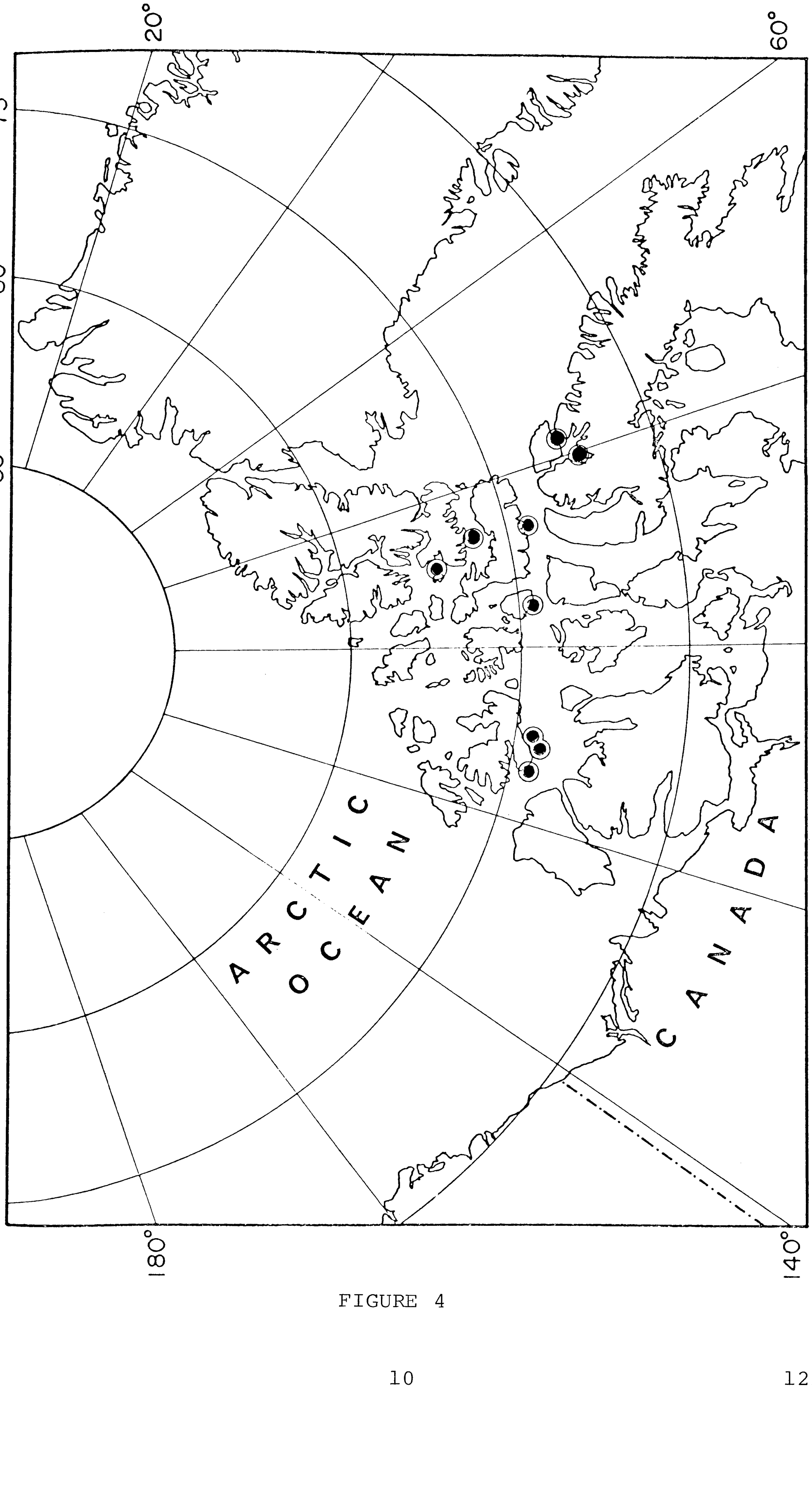


FIGURE 4

the delivery of the diver lockout submersible SDL-1 to the Canadian Armed Forces later in the year.

Four distinct objectives were established for this operation:

(1) to undertake a range of operational tasks directed at resolving a number of unknowns regarding the use of a submersible in this environment,
(2) to assess the suitability of a submersible of the Pisces type for use in this environment,
(3) to attempt to define the optimum roles of free diving, excursion diving with habitat support and submersible operations, with respect to research tasks in the Great Lakes,
(4) to obtain some experience which could delineate the most suitable submersible for maximum usefulness in this environment.

The operation was funded by the Canadian Department of Energy, Mines and Resources, Great Lakes Division. The program accepted participation by two industrial firms, three Federal government agencies, one Province of Ontario government agency, three Canadian Universities (all situated in Ontario), and the University of Michigan.

The support facilities comprised a barge with deck mounted 27 metric ton crane and a single screw 21 meter tug. A helicopter was made available by the Canadian Department of Transport for appropriate duties. Its main contribution was in the realm of passenger transport and logistics support.

Two separate areas were selected for the conduct of the operation. The first eleven dives were made in west central Georgian Bay at the northernmost tip of the Bruce Peninsula. This was followed by five dives near the west end of Lake Erie. The Georgian Bay area was chosen because of the proximity of water in excess of 120 meters deep with good visibility in a region known to have an abundance of underwater bedrock exposure. The Lake Erie area was chosen for contrast; visibility was known to be poor, the maximum water depths was approximately 15 meters and bottom conditions were expected to be continually active due to the high energy content and shallow water which characterizes that area.

The program embraced studies of; fish populations and behaviour, water turbulence and diffusion, detailed lithology of bottom sediments, exposed bedrock weathering and erosion, the occurrence of magnesium nodules, the occurrence of peat deposits, the presence of sand waves on the floor of Lake Erie with a first attempt at assessing their dynamic behaviour.

It was an ambitious program undertaken by scientists gaining their first experience in the operation and use of a submersible. In spite of this, and the relative inexperience of the submersible crew, the results were favourable though not an outstanding success.

In fact, the final assessment was that less than one fifth of the total program objective was accomplished. Three main factors were considered responsible for this short-fall, namely;

(a) unfavourable and persistently poor weather conditions,
(b) inexperienced personnel expecting to do too much too quickly,
(c) equipment failures, with the submersible giving rise to more than its fair share.

Yet despite the ways in which the operation was hampered, many dives were extremely successful, and the most important results may be summarized as follows;

(1) an opportunity was given to scientists to observe the living environment at first hand,
(2) the submersible provided researchers with the ability to search, scan and selectively sample the bottom and to reject or retain sample material at will,
(3) the program provided the ability for participants to install, test and observe the performance of their chosen equipment and learn much that will be of great future value thereby.

Pisces III was considered to be a very good submersible type by those participants whose interest lay in the geological and lithological aspects of the program. However, those who gave their attention to the fish population and behaviour found it inadequate in that it was too noisy in spite of lacking adequate speed and maneuverability. It was concluded as well that an enhanced viewing capability was essential and that the level of illumination produced by the submersible's external lights should be infinitely variable from full on to off. In passing it may be worthy of note that full acrylic spheres are now manufactured which are certifiable as pressure hulls for shallow (200 meter) submersibles. This should present an excellent solution to the viewing problem.

Notwithstanding all the adversities and shortcomings which the participants experienced during this brief but intensive operation, all were exhilarated by the personal experience of being dived in a submersible, all were impressed with the extent to which visual observation expanded their knowledge, all were unanimous in endorsing the use of the submersible as a powerful research tool. And, of course, each group could grasp at once the benefits of a submersible especially designed to optimize their particular area of endeavour.

The formal report of this operation is being co-ordinated by the Canada Centre for Inland Waters, P.O. Box 5050, Burlington, Ontario. Reference 6.

The third Canadian Arctic Operation Employing Manned Submersibles has already been alluded to - Pisces III with the support vessel, Hudson Handler, working in Hudson Bay during August and September 1970, under contract to Aquitaine Company of Canada Ltd.

It was for the performance of this operation that the support vessel M.V. Hudson Handler was designed and built. In order to meet an extremely stringent time schedule and to operate within a very limited budget, an inexpensive vessel of modular construction, capable of rapid fabrication and rail transportable to further minimize the time required to get it into Hudson Bay, was seen as the only feasible solution. The design also provided the opportunity to incorporate certain concepts which operational experience had suggested as desirable in a submersible support vessel, the most revolutionary, in addition to its modular construction and transportability, being a ramp launch/recovery system.

One module of the vessel is hinged along its foremost transverse, the hinge point being almost exactly midway between the vessel's stem and stern. This module is watertight and contains internal sub-divisions. When filled with air its deck line is horizontal and co-planar with the deck level of the vessel. When partially flooded the stern end sinks and the deck line forms a ramp inclined downward some 17 degrees leading into the water. The deck is fitted with rails and a carriage into which the skids of Pisces III fit. The carriage is moved along the rails by a winch and drag line arrangement. When the submersible is on board the support vessel, the carriage is fully forward and locked rigidly in place. To launch the submersible, sufficient water is allowed to flood into the ramp section to submerge its stern end some ten feet below the surface. The carriage is allowed to run aft until the submersible floats free. To recover, a line is used to haul the submersible into the carriage which is then drawn fully forward. The water is blown out of the ramp section which then returns to the horizontal.

The stern end of the ramp section is restrained by shock-absorbing preventers which, while protecting the ramp from damage, permit it to synchronize relatively well with prevailing wave action. Recoveries in seas with wave amplitudes of up to 3.5 meters have been accomplished.

It may be of interest to note that in order to further economize on time, the modular sections were fabricated near Winnipeg and, after transport by rail, were assembled in Churchill, and all within a period of just under six weeks!

The operation itself was considerably less exciting than the preparations. Pisces III was airlifted from Halifax, Nova Scotia, to be embarked onboard Hudson Handler for launch/recovery trials at Churchill. The task force then travelled some 400 kilometers to the site of an oil well just south of the geographical centre of Hudson Bay. The depth of water at the well site is approximately 180 meters.

The purpose of the operation was to relocate the well head and survey the preventer stack from Pisces III. The intention was to spend 30 days on site. However, the task was successfully completed in 15 days. During this time 10 launch and recoveries of the submersible were made. A 5 meter rubber boat with 40 h.p. outboard motor was used to run a 2 cm floating line out to the submersible as a hauling-in line. The boat was in fact the limiting factor relative to weather conditions for recovery.

The well head, whose geographic position was accurately known, was found on the first dive. Thereafter, sufficient dives were made over a period of 12 days, and during some fairly heavy weather, to accomplish the full objectives of the operation. Having departed Churchill on August 19, the task force was back alongside on September 3. Pisces III was returned to Vancouver by air. The Hudson Handler was dismantled and returned to Vancouver by rail.

A tribute to the success of this operation and the satisfaction of the customer regarding the capability of a manned submersible to do useful work in the field of oil exploration is the fact that Pisces III with Hudson Handler is at this time again working in Hudson Bay for the Aquitaine Company of Canada Ltd.

The present program is significantly more demanding however. During the spring of this year two coring devices were developed especially for this operation. One is a small submersible mounted corer capable of taking a 1.5 cm core some 22 cm long. The core remains in the core drill, and if more than one such core is required at a given site or during a given dive, core drills may be changed using the submersible's manipulator. The second corer is a surface controlled corer handled from the deck of the Hudson Handler. This corer is lowered to the bottom where it levels itself and can then take a 4 cm core 3 meters in length, input power being sent down the combined power, control and handling umbilical line.

The total program requires coring at some 50 sites around the entire periphery of Hudson Bay. Since the geographical location of these sites must be known with great accuracy, the Hudson Handler has been fitted with a Satellite Navigation System for this purpose.

By agreement with the Aquitaine Company of Canada Ltd., two scientists from the Canadian Department of Energy, Mines and Resources have also been invited to accompany the task force on this operation. They are equipped to do work with side scan sonar, and perform certain seismic survey work.

The operation is due to be complete before the end of September. The report will follow in due course.

THE FUTURE

Perhaps the major difficulty in making any comment on the future of the manned submersible is to give adequate scope to one's imagination. There is already a pressing need for man to learn all that he can about the marine ecosystem, and ideally he should do this in advance of having to exploit the oceans for food and raw materials. Yet the need for such exploitation is upon us, so the need to advance his knowledge must be accepted as being a matter of urgency. The ocean engineering system of which the manned submersible is the key element must undoubtedly play a major role in both the understanding, exploration and exploitation of this vast, delicate ecosystem.

The future of the manned submersible is as wide as man's imagination can compass.

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